Review of the Population Status and Management of Double-Crested Cormorants in Ontario

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Abstract: We prepared this review of the status and management of double-crested cormorants *(Phalacrocorax auritus*) in Ontario, with management options, in response to concerns expressed about possible negative impacts of large numbers of the birds on fish stocks, and vulnerable, threatened and endangered species. Double-crested cormorants are native to Ontario and were first recorded breeding on Lake of the Woods in northwestern Ontario in the late 1700's. The birds spread eastward to colonize all of the Great Lakes by the 1930's. A decline in cormorant populations on the Great Lakes from the 1950's to the 1970's has been attributed mainly to chemical contaminants and resulting lower reproductive success. Populations on the Great Lakes have increased dramatically since the 1970's in response to reduced contaminant levels and increased abundance of small forage fish. There were an estimated 36,000 breeding pairs on the Canadian Great Lakes in 1997, with increasing numbers found on inland water bodies. Double-crested cormorants are protected in Ontario, and there are no population control programs. With increasing numbers of the birds, population management options were considered, ranging from no controls, to controls in specific local areas, to widespread controls. The latter does not appear to be justified because evidence suggests that cormorants have not had significant effects on sport, commercial or small forage fish on an ecosystem basis. Control measures in specific local areas may be justified for certain management purposes, such as protection of endangered species.

Keywords: double-crested cormorant, population control, management options, Ontario

The abundance of double-crested cormorants (DCCO's) in Ontario has increased dramatically over the last 2 decades. This situation has prompted intense public discussion and many inquiries about the impact of this increase. For example, Ontario sport and commercial fishermen have expressed concerns that increasing DCCO numbers are having adverse effects on fish stocks and that steps should be taken to control cormorant populations. Other interest groups and interested parties, including naturalist groups, maintain that DCCO's are not having significant impacts on fish stocks, are part of the natural ecosystem, and do not warrant the implementation of control measures. However, there are some concerns about the potential destruction of wildlife habitat—especially that of vulnerable, threatened and endangered species—caused by nesting DCCO's.

In response to these concerns, we reviewed the population status of, and the environmental impacts caused by, DCCO's in Ontario. A draft report was prepared summarizing the history and current status of DCCO's in Ontario, based on an overview of the scientific literature, discussions with cormorant experts, a survey of Ministry of Natural Resources (MNR) field staff, and a national survey of other Provincial natural resource management offices. The draft report also presented a series of management options. Public consultation on the draft report began on February 23, 1997. The draft report was distributed to other government agencies, interest groups, and other interested parties who had contacted MNR regarding DCCO's. The draft report was also posted, as a registry proposal file, for a 30-day public comment period, on the Electronic Registry in accordance with the requirements under the Ontario Environmental Bill of Rights. The objectives of the consultation process were to ensure as complete an information base as possible, to ensure accurate interpretation of existing information, and to determine reviewer thoughts on management options. The comments received were considered and used to produce a revised report at the end of 1997 (Korfanty et al. 1997).

The purpose of this paper is to summarize the history and updated population status of DCCO's in Ontario prior to developing and recommending a management approach for the Province. Any recommended management approach will need to be consistent with the following MNR goals: (1) to secure healthy ecosystems in terms of healthy populations and communities, integrity of natural processes, and biological diversity; (2) to identify and protect provincially significant natural heritage features and landscapes; and (3) to provide a variety of opportunities for enjoyment, appreciation, and use of fish and wildlife, including opportunities for viewing and fishing.

Environmental Bill of Rights

The MNR's interest in environmental protection and ecological integrity is further expressed through its "Statement of Environmental Values" (SEV), prepared under the Ontario Environmental Bill of Rights. The SEV not only records MNR's commitment to the environment but also indicates how MNR will be accountable for ensuring consideration of the environment in its decisions.

History

The DCCO is a conspicuous, black, diurnal bird that is native to Canada. Cormorants are very sociable birds and nest in colonies on undisturbed islands with a convenient food supply nearby. They build their nests in trees near water or on the ground (i.e., on rocks, islets, cliff tops, and ledges) on the same islands in successive years. In establishing a new colony, DCCO's often occupy an island for a few years before nesting. Egg-laying begins in late April and early May following courtship and nest-building activities. Eggs hatch in about 25 to 29 days, and the chicks are fledged in about 42 days and reach independence in about 70 days (Cadman et al. 1987, del Hoyo et al. 1992, Weseloh and Collier 1995).

DCCO's breed throughout Canada from the Pacific coast, through the Canadian prairies and the Great Lakes, and along the St. Lawrence River to the Maritime Provinces and Newfoundland. Breeding pairs have not been recorded in the Yukon, but there is evidence of breeding in the Northwest Territories islands in James Bay off the Quebec coast (Strutton Island, Caroline Shoals, Eastmaine and Wayrock) (D. McRae, pers. commun.). In Ontario, DCCO's have been breeding on Lake of the Woods at least since 1798. The species moved eastward into Lakes Superior and Nipigon between 1900 and 1920, with the first nesting in the Great Lakes occurring on the far western end of Lake Superior in 1913 (Smith 1957). DCCO's were nesting in the North Channel of Lake Huron by 1931 and established breeding colonies on Lake Ontario by 1938 and on Lakes Erie and St. Clair by 1939 (Cadman et al. 1987, del Hoyo et al. 1992, Weseloh and Collier 1995).

DCCO's are now commonly found inland around bodies of fresh water, along the shores of large lakes and, less frequently, around smaller inland lakes. The Great Lakes population migrates south along the Mississippi River or travels east to the Atlantic coast and then south to the gulf coast (Cadman et al. 1987, del Hoyo et al. 1992, Weseloh and Collier 1995).

DCCO's feed primarily on small, shallow-water fish. Prey species vary locally and regionally and in Ontario include alewife *(Alosa pseudoharengus),* rainbow smelt *(Osmerus mordax,)* yellow perch *(Perca flavescens),* and, to a lesser extent, white suckers *(Catostomus commersoni),* pumpkinseed *(Lepomis gibossus),* sculpins *(Cottus* spp.), crappie *(Pomoxys* spp.), bass *(Micropterus* spp.), and sticklebacks (Gasterosteidae) (Weseloh and Collier 1995, Neuman et al. 1997).

DCCO's expanded their breeding range and colonized the Great Lakes between the 1900's and 1950's. By the fifties, the DCCO population on the Canadian Great Lakes peaked at about 900 nests (i.e., about 1,800 adults plus juveniles and nonbreeding birds). By 1946, sport and commercial fishermen claimed that DCCO's were feeding on large quantities of desirable commercial and sport fish, and they called for a DCCO control program. In response to these concerns, a DCCO control program was introduced in Ontario, primarily on Georgian Bay (Cadman et al. 1987, Weseloh and Collier 1995).

Early control measures included the destruction of eggs, but the birds responded by laying more eggs at new sites. Later methods of control included spraying eggs with a solution of formaldehyde and soap, which suffocated the developing embryo but left the eggs intact. Hatching failure could also have been due to the direct toxic effects of the formaldehyde solution. DCCO pairs continued to incubate sprayed but intact clutches for the full incubation period until it was too late in the season to start a new clutch (Christens and Blokpoel 1991, Weseloh and Collier 1995).

During the early DCCO control program, fish harvesters began organized, illegal, annual destruction of colonies by shooting adults and destroying eggs, nests, and young. Such attempts probably slowed the growth of the DCCO population during the 1940's and 1950's but did not reduce the overall Great Lakes population to any great extent. The DCCO control program remained in effect on the Canadian Great Lakes until 1966 (Weseloh and Collier 1995).

Increased concentrations of toxic chemicals in the Great Lakes between the 1950's and 1970's devastated DCCO populations. The total number of nesting pairs on the Canadian Great Lakes declined from 900 in the early 1950's to about 125 in 1973—an 86-percent reduction. DCCO's stopped breeding on Lakes Michigan and Superior, and only 10 pairs remained on Lake Ontario by 1973. Accumulation of dichlorodiphenyltrichloroethane (DDT), dichlorodiphenyldichloro-ethylene (DDE), and polychlorinated biphenyls (PCB's) in the body fat of DCCO's caused eggshell thinning and reproductive failure. In 1972, 95 percent of DCCO eggs broke or disappeared during incubation. Reproductive success declined from about 2 chicks/pair to 0–0.2 chicks/pair, a level insufficient to offset adult mortality. In addition, deformities began to appear in the early 1970's, including crossed bills, club feet, extra digits, and eye and skeletal abnormalities. During that decade, DDT and other toxic pesticides were banned (Weseloh and Collier 1995, Weseloh et al. 1995).

The reproductive success of DCCO's improved as levels of DDT and other contaminants declined in the Great Lakes. DCCO's rapidly increased from about 125 pairs in 1973 to more than 38,000 pairs on the Canadian Great Lakes by 1993. In 1981, the Canadian Wildlife Service (CWS) found 907 nests on the Great Lakes in Ontario. By 1985, field crews found 2,221 nests at the same sites (a 145-percent increase), plus an additional 1,138 nests at 12 new sites, for a total increase of 270 percent (an average of 39 percent annually) between 1981 and 1985. By 1991, the average annual rate of increase was approximately 35 percent, and in 1993 the total number of colonies on the Canadian Great Lakes was more than 100. Eggshell thickness and reproductive success had returned to relatively normal levels for this species (Cadman et al. 1987, Weseloh and Collier 1995).

This dramatic increase in DCCO populations cannot be attributed solely to decreased contaminant loads in the Great Lakes. Their rate of increase following the DDT ban has been much higher than their rate of increase during their initial migration into the Great Lakes during the 1930's and 1940's. Alewife and rainbow smelt, which are the primary food source for DCCO's in the Great Lakes, had significantly increased in number in response to the decline of large predatory fish. Alewife and rainbow smelt travel in large schools and provide an excellent food supply for DCCO's. The dramatic increase in DCCO's may, therefore, be attributed to this abundant food supply in addition to declining DDT levels (Weseloh and Collier 1995, Weseloh et al. 1995).

Historical declines in the Great Lakes fish populations that led to the DCCO control program appear to have been caused by overfishing, invasion by sea lamprey, and loss of aquatic habitat (e.g., loss of spawning grounds and contamination by pesticides and other toxic chemicals). Significant declines in lake trout *(Salvelinus namaycush)* occurred in Lake Ontario in the late 1930's and 1940's and in Lake Huron during the 1940's and 1950's. In response to the decline of large predatory fish, populations of small prey fish (mainly rainbow smelt and alewife) increased dramatically, allowing DCCO populations to expand following the DDT ban. Even with intensive salmon *(Oncorhynchus* spp.) and trout stocking in the Great Lakes during the 1980's, alewife were still very abundant and could be heavily preyed upon by DCCO's in many parts of the Great Lakes (Weseloh and Collier 1995, Weseloh et al. 1995).

Recent Changes in the Fish Communities in Lake Ontario and Possible Effects on Cormorants

According to Schaner and Schneider (1996), alewife and rainbow smelt are the most abundant plankton-feeding fish in Lake Ontario. Their once large populations have declined over the last few years mostly due to two factors. First, decreased nutrient loading within the Lake Ontario watershed has led to decreased plankton production. Less plankton supports fewer alewife and smelt. This effect has more recently been compounded by the accidental introduction of zebra mussels *(Dreissena polymorpha)* and quagga mussels*(D. bugensis),* which divert energy flow from the pelagic to the benthic community, away from the pelagic-feeding alewife and smelt. Second, the stocking of large salmonines was high until the early 1990's. Alewife and smelt are being affected from both sides, by high predation by salmon and trout and limitations on plankton availability. As a result of declining alewife and smelt numbers, stocking of salmonines has been reduced. Currently, the fish communities of Lake Ontario are in a state of flux. DCCO populations will possibly show similar fluctuations until balance within the pelagic fish community occurs.

Current Situation

A survey of MNR staff (November 1996) documented the occurrence of DCCO's on the Great Lakes and a number of inland lakes throughout the Province (Korfanty et al. 1997). The survey was not a comprehensive list of all sightings of DCCO's but gave a representation of occurrence throughout the Province. Although reports of increasing DCCO numbers were common, it appears that in some areas DCCO numbers are beginning to stabilize. Some areas reported increasing numbers of nonbreeding DCCO's on inland lakes for feeding and loafing.

Table 1 shows recent estimates of DCCO populations on the Canadian Great Lakes. Current populations in Lakes Huron, Ontario, and Erie are larger than in Lake Superior, probably due to the availability of nesting sites and food. Lake Erie is more productive than the other Great Lakes, but there are relatively few islands where DCCO's can nest. Lakes Huron and Ontario have numerous nesting islands and, despite their lower productivity, these lakes still have a large enough prey base to support large numbers of DCCO's. Lake Superior also has numerous islands, but it is less productive and consequently has a smaller forage base (Weseloh and Collier 1995).

DCCO populations are expected to stabilize in the Great Lakes watershed (Weseloh and Collier 1995). Indeed, the recent rate of population increase in the Great Lakes is less than the rate of increase in past years. The current overall annual rate of increase for the Canadian Great Lakes is 3.7 percent above 1993–94 levels (D. V. Weseloh, pers. commun.). Ludwig and Summer (1997) predict that, left alone, the DCCO population for the upper Great Lakes may continue to grow for another 7 to 9 years before levelling off. These predicted rates are similar to that of the ring-billed gull population, which has achieved a balance in the upper Great Lakes after its explosive growth between 1955 and 1972 (Ludwig and Summer 1997).

Table 1. Approximate number of pairs of DCCO's on the Canadian Great Lakes, 1997[1]

Body of water	Number of pairs
St. Lawrence River	727
Lake Ontario	8,205
Lake Erie	7,434
Lake Huron	
North Channel	6,255
Georgian Bay	7,688
Main body of Lake Huron	3,747
Lake Superior	1,985
Total	[2]36,041

[1]Source: D. V. Weseloh, pers. commun.

[2]A 3.7-percent increase from the 1993–94 level of 34,701 pairs.

Current Related DCCO Health Problems

Colonization, Growth, and Decline

Animals colonizing new areas often show an initial period of unrestricted growth, especially if habitat conditions are excellent (e.g., good food supply, water quality, and nesting sites). Eventually, habitat conditions cannot support unrestricted population growth, and the population may decline in response to disease, reduced food supplies, lack of available nesting sites, predation, or competition. The population may then crash or stabilize at a lower level (Weseloh and Collier 1995).

Between 1992 and 1994, the number of breeding DCCO pairs on Little Galloo Island in Lake Ontario, the largest colony on the Great Lakes, declined by 31 percent. In 1994, the DCCO population of Lake Ontario decreased by 6 percent, the first observed decline in more than 15 years. In 1992, Newcastle disease killed up to 30 percent of the young DCCO's in several colonies (Weseloh and Collier 1995).

Contaminant Problems in DCCO's—Indicators of Ecosystem Health

DCCO's are important indicators of ecosystem health. This was demonstrated by their failure to reproduce as a result of exposure to high levels of DDT, DDE, and PCB's in the Great Lakes aquatic food web. Species that currently feed in the Great Lakes are exposed to high levels of dioxin-like chemicals known to cause developmental deformities. Ludwig et al. (1996) observed a number of deformities in DCCO dead eggs, live eggs, and hatchlings, in relation to exposure to PCB's and polychlorinated diaromatic hydrocarbons in the Great Lakes.

The occurrence of deformities within the waterbird community of the Great Lakes is still much greater than the occurrence of deformities in control groups in northern Lake Winnipegosis in Manitoba. Although total PCB's have decreased in the Great Lakes, PCB-related toxicity has not necessarily decreased by the same amount. Simpler chemical analytical estimates of the total amount of PCB's in biological samples (as opposed to congener-specific analysis) are likely to result in a serious underestimation of the actual toxicity (Ludwig et al. 1996). Although DCCO populations are increasing under current contaminant burdens, deformities are still occurring. This fact suggests that contaminant-related health problems persist in Great Lakes wildlife (Weseloh and Collier 1995). DCCO's are a natural part of a large and complex ecosystem and are indicators of the health of aquatic ecosystems in Ontario. Monitoring DCCO populations and other sensitive avian species (e.g., bald eagle *[Haliaectus leucocephalus])* on the Great Lakes is essential because of the health risks resulting from exposure to toxic contaminants in the Great Lakes ecosystem.

Newcastle Disease in DCCO's

Cormorants are susceptible to Newcastle disease, a deadly, contagious virus affecting the nervous system in birds. Young birds are particularly susceptible at about 4 to 5 weeks of age, when they are losing their maternal immunity. The disease has been documented in DCCO's in Ontario and throughout Canada in 1975, 1990, 1992, and 1995. An outbreak of Newcastle disease in 1992 killed an estimated 30 percent of young DCCO's on Lake Ontario and the north channel of Lake Huron (Canadian Cooperative Wildlife Health Centre 1995; D. V. Weseloh, pers. commun). There are no reliable estimates of the total mortality at the population level, but observations suggest that hundreds or thousands of birds have died in Great Lakes colonies (E. M. Addison, pers. commun.). All occurrences or suspected occurrences of Newcastle disease in any bird species must be reported to Agriculture and Food Canada. All commercial poultry species are susceptible to the disease, and every attempt should be made to avoid contact between domestic birds and affected wild birds (Canadian Cooperative Wildlife Health Centre 1995).

Concerns About DCCO's in Ontario

The MNR has recently received many verbal and written complaints and concerns about DCCO's, including requests for control programs. Most concerns have been expressed by fishermen regarding the impacts of DCCO's on fish stocks, but concerns have also been expressed that DCCO's are destroying vegetation and displacing other birds at their nesting sites. Most of these complaints/concerns are related to the Great Lakes, but concerns have also been expressed about DCCO's on larger inland lakes (e.g., Lake Nipissing, Lake of the Woods, Rainy Lake, St. Joseph Island, Lake Nipigon, Lake Simcoe, Muskoka lakes) and the St. Lawrence River. There have been few or no complaints about DCCO's in most other parts of the Province (e.g., Chatham, Long Point Area, Lakes Erie and St. Clair, Rock Point Provincial Park [Niagara], Cambridge, Pembroke, Kirkland Lake, Cochrane, Gogama–Timmins, Chapleau, Kapuskasing, Moosonee, Geraldton, Sioux Lookout, and Red Lake).

Impacts on Fish

Some Ontario commercial and sport fishermen express concerns that DCCO's are competing with fish harvesters for large, major sport fish like lake trout and salmon, that the birds feed on the same prey fish that these large predatory fish feed on, and that cormorants deplete local supplies of smaller sport fish, such as yellow perch and smallmouth bass *(Micropterus dolomieu),* particularly in small bays and inlets on the Great Lakes.

The following questions were considered to address these concerns: (1) Do DCCO's compete with fish harvesters by eating sport and commercial fish? (2) Do DCCO's compete by eating the same prey fish that sport and commercial fish feed on? and (3) Do DCCO's deplete local stocks of sport fish?

The majority of MNR staff report no widespread evidence of DCCO's negatively affecting fish populations in most areas of the Province. Many of these reports were based on observations in the absence of scientific evidence. However, a few studies and some observations provide insight into the possible impact of DCCO's on local fish populations.

On Lake of the Woods, a large DCCO colony inhabits Three Sisters Island together with white pelicans *(Pelecanus erythrorhynchos).* The Fisheries Assessment Unit has recently concluded a 2-year study in the south sector of Lake of the Woods. Results indicate a long-term decrease in brown bullhead *(Amieurus nebulosus)* densities since the late 1970's–early 1980's, parallelling the increase in DCCO and pelican numbers on the lake. Favored nursery areas for young bullheads are the same shallow-water bays frequented by feeding DCCO's and pelicans.

On Lake Nipissing in the North Bay area, MNR staff observed regurgitated food from DCCO's during nesting observations and found some northern pike *(Esox lucius)* and walleye, although the bulk of the diet was yellow perch, pumpkinseed, and shiners (Cyprinidae).

On Lake Ontario, less than 2 percent of the prey found in DCCO pellets are lake trout or salmon (Weseloh and Collier 1995). Similarly, Ross and Johnson (1995) found that game fish, mainly smallmouth bass (1.3 percent) and salmonines (0.3 percent), made up only 1.6 percent of the diet of DCCO's in the same lake. DCCO's in Lake Ontario fed primarily on alewife, centrarchids, yellow perch, white perch, trout-perch, and rainbow smelt, which are the most commonly identified species in the pellets and regurgitate of DCCO's (D. V. Weseloh and T. Casselman, pers. commun.). Schaner and Schneider (1997), however, discuss changes within the current fish communities of Lake Ontario. With these changes, Schneider et al. (1996) propose that the continued reduced availability of alewife in the eastern basin of Lake Ontario may shift feeding pressure onto species such as smallmouth bass.

Weseloh and Collier (1995) provided a good example of how calculations are made to estimate the consumption of fish by DCCO's residing on Lake Ontario. The following data are required to estimate how much fish cormorants eat in a season: (1) How much do DCCO's eat each day? (2) How long are

DCCO's present on the Great Lakes? and (3) How many DCCO's are there in total?

The average DCCO weighs about 4.2 lb (1.9 kg) and eats about 25 percent of its weight in fish each day or about 1 lb (0.48 kg). Most adult DCCO's on the Great Lakes reside there from about mid-April to late August or early September (about 135 days). During that time, one adult DCCO will eat about 143 lb (65 kg) of fish. Most young DCCO's on Lake Ontario hatch in late May but do not start eating their "pound of fish per day" until about mid-June. Most young DCCO's remain on the Great Lakes until mid-late September, or for about 100 days. In 1991, for example, more than 40,000 DCCO's (adults and young) lived on Lake Ontario and consumed about 5 million lb (2.25 million kg) of fish. Fisheries biologists have estimated that there are 920 million lb (418 million kg) of the smaller prey fish in Lake Ontario. Salmon and trout consumed approximately 123 million lb (56 million kg) of these prey fish. These estimates suggest that sport fish took about 13.4 percent of the prey fish on an annual basis, and DCCO's took 0.5 percent (Weseloh and Collier 1995).

Weseloh and Casselman (pers. commun.) are examining the annual consumption of prey fish by DCCO's and sport fish in the eastern portion and total of Lake Ontario. They recorded 9,170 DCCO nests on 11 known colonies in Lake Ontario in 1991. These colonies are located on Eastport, Farre Island, Toronto Harbour, High Bluff Island, Gull Island, False Duck Island, Salmon Island, Snake Island, Pigeon Island, Little Galloo Island, and Bass Island. The preliminary results of the study show that there is little competition between DCCO's and sport fish (piscivores) for prey fish and that DCCO's take relatively few fish compared to the total available biomass. At this time, major studies have not addressed the possible impact of cormorants on local fish stocks in small bays or other local areas.

The Lake Huron Management Unit and Parry Sound District Office of MNR are studying the effects of DCCO's on the Lake Huron fish community (D. McLeish and P. Black, pers. commun.). Observations suggest that the rate of increase of DCCO's on Lake Huron may have declined, although survey data are required to corroborate these observations. McLeish and Black initiated a study in 1994 to determine the proportion of various fish species in the diets of DCCO's and the potential effects of cormorant predation on the fish community. Although the cormorant population and its fish consumption can be estimated fairly easily, estimating the size of the fish population for the various species in the diet is much harder. In the case of Lake Huron, only crude estimates of the total population biomass of rainbow smelt and alewife populations can be calculated.

DCCO pellets were collected from May to July 1994, and regurgitated stomach contents (i.e., boli) were collected from nestlings during May and June. The sites surveyed were Birnie Rocks, Bustard Islands, Gull Island, and Manitoba Reef. Gross annual fish consumption was estimated for adults, immatures, and juveniles in the main basin of Lake Huron, Georgian Bay, and the north channel. Preliminary results showed 7,900 food items in the pellet samples and 945 food items in the bolus samples. Investigators identified 38 prey types, of which 13 accounted for 85 percent of the DCCO diet. The 10 species of fish that constituted the majority of the diet (listed in descending order) were rainbow smelt, shiners, smallmouth bass, slimy sculpin, sunfish, alewife, yellow perch, trout-perch, white sucker, and walleye. Nonfish items (worms, insects, insect larvae, and crayfish) comprised 17 percent of the diet. Most of the adult diet (77 percent) was composed of forage species (e.g., alewife, rainbow smelt, slimy sculpin, and shiners). Three sport fish (smallmouth bass, yellow perch, and walleye) accounted for 22 percent of the food items in the sample (McLeish and Black, pers. commun.).

Preliminary results also show that DCCO's consumed 4,177.3 metric tons of fish from the whole of Lake Huron. Most of the fish eaten by cormorants came from Georgian Bay (50 percent), followed by the north channel (33 percent) and the main basin (17 percent). The total amount of fish consumed by DCCO's represented 29 percent of the total extraction of fish from the whole lake: 3,400.8 metric tons (or 24 percent) was the total commercial harvest and 6,787.2

metric tons (or 47 percent) was the estimated recreational harvest, for a total extraction of 14,365 metric tons of fish from Lake Huron. The proportion of fish consumed by cormorants, in comparison with the total extraction of fish, varied across the basins. DCCO's consumed 70 percent of the total fish extracted from the north channel, 26.4 percent of the fish extracted from Georgian Bay, and 15.6 percent of the fish extracted from the main basin. DCCO's consumed about 2.5 percent of the estimated biomass of alewife and 1.8 percent of the estimated biomass of rainbow smelt (McLeish and Black, pers. commun.).

McLeish and Black's preliminary results from Lake Huron suggest that DCCO's consume more fish biomass than is harvested by the commercial fishery but less than is taken by the recreational fishery. In total, DCCO's consume roughly half as much fish, by weight, as that harvested by commercial and recreational fishermen. These preliminary results show that although DCCO populations are capable of consuming a large biomass of fish, they are opportunistic feeders and their diet consists primarily of forage species. Fish species of interest to sport or commercial fisheries comprise a smaller proportion of the diet. DCCO's affect the lower trophic levels of the Lake Huron fish community and do not appear to be impairing the overall sustainability of fish populations and fish community dynamics on Lake Huron. The rapid expansion of DCCO populations on Lake Huron suggests that the fish community is unstable and lacks the stabilizing influence of a top piscivore predator. The invasion and expansion of species such as smelt and alewife have created conditions favorable to the expansion of DCCO's (McLeish and Black, pers. commun.).

A study by Neuman et al. (1997) clearly demonstrates spatial and temporal differences in DCCO diets on Lakes Ontario, Huron, and Erie and finds little evidence of breeding DCCO's as significant competitors for commercially important predatory fish. Despite these findings, caution is needed when making inferences about DCCO diet based on studies with limited sampling across time or space.

With respect to the third concern, that DCCO's are depleting local stocks of sport fish, cormorants have increased in some local bays and inlets on the Great Lakes, and their consumption levels could be a factor in declines of local populations of yellow perch and smallmouth bass. In Lake Ontario, many fishermen report reduced catches of yellow perch and several panfish species in local areas such as Presqu'ile and Wellers Bay, which the fishermen attribute to large numbers of cormorants. If a local colony of hundreds of DCCO's should use a small bay to feed on a regular basis, they could affect the local fish population. Neuman et al. (1997) suggest that concentrated foraging by DCCO's on sport fish during specific periods such as during a stocking release may have biologically significant effects on local fish survival and recruitment.

Surveys are required in site-specific areas, identified as potential DCCO "hot spots," to determine if local populations of yellow perch and smallmouth bass are declining and to identify factors responsible for these declines (e.g., DCCO consumption, overfishing, loss of habitat). These surveys need to carefully consider the effects of the technique of diet determination on the study results and also be set up to sample on a scale appropriate to the question being posed. For example, an assessment of local impacts of DCCO predation should focus on that area only, ensuring that temporal variation is determined (Neuman et al. 1997). Diets of breeding DCCO's also vary between egg and nestling stages as well as on the bases of colony location to food source, fish spawning dates and fish habitat structure.

Impacts on Habitat

Colonies of DCCO's can negatively affect vegetation at their nesting sites. DCCO's strip the leaves from trees, and the combined weight of the birds and their nests can break branches. The birds' excrement also falls on the leaves and ground from the nests, damages or kills the leaves and ground vegetation, and eventually kills the nest trees themselves (Moore et al. 1995). Severe damage to vegetation could eventually lead to soil erosion.

MNR staff and the CWS suspect that expanding cormorant colonies have killed trees and shrubs on several islands in Lake Ontario, including Snake

Island, West Brothers Island, False Duck Island, Scotch Bonnet Island, and Gull Island. There has been serious damage to rare trees at High Bluff Island and Presqu'ile Provincial Park, and cottonwoods (i.e., nesting trees) have been damaged at Tommy Thompson Park in Toronto.

Habitat destruction is a major problem on the Carolinian islands in western Lake Erie. East Sister Island, the largest Carolinian island, contains a mixed species colony. There are 2,000–3,000 DCCO nests and very noticeable tree damage and die-off. For example, stands of Kentucky coffeetrees *(Gymnocladus dioicus)* are starting to die from the "white-washing" effect of DCCO excrement. There is also concern about cormorants' damaging the vegetation on Lake Huron's Chantry Island, which is classed as an Environmentally Significant Area. Tree damage and defoliation have also been reported on islands in Golden Lake (Pembroke area).

The vegetation on Three Sisters Islands, Lake of the Woods, has also changed over a 20-year period from extensive tree and shrub cover to standing dead trees, such as elms *(Ulmus americana)* and limited ground vegetation. This phenomenon is attributed to DCCO and pelican excrement. The islands provide nesting habitat for great horned owls *(Bubo virginianus)* and, recently, a pair of bald eagles, which are adept at taking juvenile DCCO's.

Further information and monitoring are required for better identification of the location, extent, and cause of destruction of critical vegetation or habitats (e.g., the habitats of vulnerable, threatened and endangered species). Information is also needed on the recovery of vegetation after the exclusion, decline or elimination of DCCO's.

Observations of Impacts on Other Bird Species, as Reported by MNR Staff

Nesting DCCO's may be affecting other nesting birds, but these impacts have not been well documented. For example, on Lake Erie's East Sister Island and Middle Island, DCCO nesting activities may negatively affect black-crowned night-herons (BCNH's) *(Nycticorax nycticorax hoactli).* DCCO's usually nest above BCNH's, and the "rain" of excrement down onto heron nesting areas makes the area uninhabitable for the latter species. DCCO's may also strip foliage that BCNH's require as cover.

In Hamilton Harbour, increasing numbers of DCCO's nesting in cottonwood trees corresponded to a decreased use and eventual abandonment of these trees by BCNH's (Moore et al. 1995). At Tommy Thompson Park, the expanding DCCO nesting population is eliminating nesting herons from some areas.

There is also concern about the possible impact of DCCO's on the nests of the common tern *(Sterna hirundo)* if cormorants move onto the islands in the St. Lawrence River. Herring gulls *(Larus argentatus)* and ring-billed gulls *(L. delawarensis)* are also a threat to common terns.

Tern and gull populations have been abundant on the central Georgian Bay Islands for about 35 years. MNR staff have observed DCCO's occupying the same habitat sites as the terns and gulls. Although DCCO's access the same food sources as these other birds, the cormorants feed directly under water, whereas terns and gulls are surface feeders. There should be no overlap in their feeding habits. However, on small islands DCCO's may displace previously nesting gulls and possibly terns.

On Nottawasaga Island in Collingwood, BCNH's, great blue herons *(Ardea herodius),* green herons *(Butroides virescens),* and great egrets *(A. alba*) nest in trees and shrubs. Ring-billed gulls and herring gulls nest on the ground. DCCO's arrived on Nottawasaga Island about 3 years ago and have been implicated in the defoliation of vegetation on this island. MNR staff suspect that gulls and DCCO's will dominate the island in 5 years.

DCCO's appear to be damaging heronries in eastern Lake Superior due to the destruction of nest trees and competition for nests. The Flower Pot Islands in Batchewana Bay support a heronry that is threatened by competition from DCCO's. Cormorants are occupying the old heron nests and have destroyed much of the vegetation with their excrement.

Further information and monitoring are required to determine the locations, extent, and significance of the effects of DCCO's on other species. Cormorant exclusion experiments could be conducted to document recovery of vegetation.

Protection of DCCO's in Ontario

DCCO's are not protected federally in Canada under the Migratory Bird Convention Act. They are protected and managed under Provincial law, and in Ontario under Section 55 of the Ontario Game and Fish Act, R.S.O. 1990, c. G.1, which states that "No person shall hunt any game bird during the closed season or any other bird at any time, except crows, cowbirds, blackbirds, starlings, house-sparrows and birds, other than pheasants or Hungarian partridge, released under Section 32." However, the Game and Fish Act is not binding on the Crown as stated in Section 11 of the Interpretation Act, R.S.O. 1990, c. I.11. The section reads, "No act affects the rights of Her Majesty, Her heirs or successors, unless it is expressly stated therein that Her Majesty is bound thereby. R.S.O. 1980, c.219, s.11." This could allow for control of DCCO's by MNR employees.

DCCO Control

There have been several cases of unofficial, unauthorized DCCO control in Canada. The CWS and Provincial departments of natural resources across Canada have reported that breeding colonies of DCCO's are being, or have been, disturbed by people purposely entering the colonies on foot or disturbing the colonies by boat. These practices often lead to adult birds abandoning their nests, leaving their chicks exposed to the elements and predation. CWS and the Provinces also reported that DCCO colonies have been invaded for the purpose of destroying eggs, killing chicks, and shooting adults.

In 1993, a number of breeding DCCO's were shot on Pigeon Island in eastern Lake Ontario near Kingston, ON. Ewins and Weseloh (1994) reported that on May 14, 1993, most nests on Pigeon Island contained 3–4 eggs. On June 2, 818 nests were counted, most containing well-incubated eggs, and at least 1 egg had hatched in each of 77 nests. On June 10, only a few DCCO clutches had hatched, and many nests were empty. Investigators found about 50 dead adult DCCO's around the perimeter of the island, and 5 adults were injured. It is suspected that closer to 100 birds were killed or injured. About 100 freshly fired 12-gauge shotgun cartridges were found at the water's edge. On June 16, only 570 nests were counted; thus, 248 nests (or 30 percent) had disappeared between June 2 and 16. This reduction probably resulted when one or both adults were shot or when the contents of the nests were removed by either human interference or gull depredation. Only 151 DCCO chicks, plus 24 eggs, were present in the colony, an average of 0.3 young/nest. Most of the young were also small for the time of year. On July 28, only 100 large or fledged young DCCO's were found on Pigeon Island, an average of 0.2 young/nest. Since the late 1970's, most Great Lakes colonies have produced an average of 1.7 to 2.2 young per active nest. Productivity from the colony should have been closer to 1,391 to 1,780 young for 818 nests (Ewins and Weseloh 1994).

Pigeon Island saw the first case of intensive human disruption of breeding DCCO's in the Canadian waters of Lake Ontario since cormorant populations began to recover from the effects of organochlorine contamination. Despite loss of breeding adults and production in 1993, major reductions in breeding numbers at Pigeon Island or in Lake Ontario are not expected as a result of this shooting because Pigeon Island has seen an average annual increase of about 36 percent. Other instances of recent killing of breeding DCCO's in Lake Ontario occurred in 1984 at Little Galloo Island, where more than 600 chicks were found dead as the result of a combination of poor weather conditions and vandalism. Large rocks had been placed in some nests on top of eggs or young. Also, in June 1992, more than 12 adult DCCO's were killed along the eastern shoreline of Little Galloo, probably by being shot from a nearby boat (Ewins and Weseloh 1994).

Authorized techniques (e.g., shooting adults, hunting seasons, harassing with flare guns, and oiling eggs) have not been successful in controlling DCCO's over large geographic areas or in the longer term. Egg-spraying of ground nests and culling of breeding birds in arboreal habitats reduced breeding DCCO's from an estimated 17,854 pairs to about 12,000 pairs over a 3-year period in the St. Lawrence River estuary, but periodic control measures were considered necessary to maintain the population at a desired level (Bédard et al. 1995). Listing DCCO's as a game species for hunting purposes raises social issues because cormorants are considered inedible. Oiling of eggs can be done only on land (not in trees) and is time consuming, costly, and inefficient. It has to be repeated annually because breeding adults continue to reproduce. Egg-oiling can also increase the risk of spreading Newcastle disease to domestic poultry. The virus causing Newcastle disease can be carried on the clothing of people leaving infected colonies. Oils used on eggs in the past also contained varying amounts of toxic aromatic compounds. Oil used in a control program should be safe for people to use during application, easy to apply, and environmentally benign (i.e., not contain toxic chemicals) (Christens and Blokpoel 1991). Shooting tree-nesting DCCO's might also be required to suppress cormorant populations, but doing that could result in the incidental mortality of other bird species that might abandon their nests (J. Ludwig, pers. commun.).

Christens and Blokpoel (1991) studied the effectiveness of white mineral oil (Daedol® 50 NF) in preventing herring gull and ring-billed gull eggs from hatching. Daedol 50 NF is a chemically inert, nonpoisonous, highly purified (100-percent pure), U.S. Pharmacopoeia-approved, white mineral oil that is colorless, odorless, and tasteless. The first three sprayings suppressed hatching in 99.6 percent of the eggs. Adult gulls continued to incubate the treated eggs well after the expected hatching date and did not establish new nests elsewhere. Christens and Blokpoel (1991) concluded that spraying with Daedol 50 NF should begin 20 days after the first completed clutch in the colony has been observed and be followed by a second and third spraying at 12 and 24 days. Spraying eggs with mineral oil will prevent the production of young but will not reduce the number of nesting adults in the colony. Spraying at colonies that are almost fully occupied will not prevent the growth of these colonies because the nesting adults will attract new nesting adults to the colony (Christens and Blokpoel 1991).

Daedol 50 NF does not contaminate the environment but is relatively expensive in comparison with other oils. Alternatively, one could remove and dispose of DCCO eggs, but this method is labor intensive and must be continued throughout the breeding season because adults will continue laying eggs one or more times during the breeding season. Egg shaking is another method but is also labor intensive (Christens and Blokpoel 1991).

A majority of MNR staff surveyed in November 1996 believe, based on current biological information, that there is no need to manage or control DCCO's on a large scale. Many MNR staff view DCCO's as part of the ecosystem and believe that nature should take its course in controlling their numbers. Human-caused changes in the Great Lakes (e.g., the introduction of alewife and smelt) have disrupted the natural balance, and now DCCO's are thriving in this altered environment.

However, there may be a few site-specific areas where DCCO control might be warranted to protect vulnerable, threatened, or endangered species or to protect critical habitat, such as the Carolinian habitat on East Sister Island in Lake Erie. Sensitive areas need to be clearly identified, delineated, and assessed to determine whether DCCO's are, indeed, the problem, to determine if control is warranted, and to determine how control can be implemented without impacting other avian species. Public consultation would also be required (e.g., Environmental Bill of Rights process). DCCO control in site-specific areas may not be successful in maintaining desired population levels in the long term because these birds are widely distributed, are opportunistic, and are adaptable in finding alternative habitat and colonizing new areas.

An international meeting of the Great Lakes Cormorant Group was held on November 8, 1996, in Ohio, to review the status of DCCO's in and near the Great Lakes and to discuss management issues. The group agreed (Lewis 1996) that

> there is not strong justification at present for implementing large-scale DCCO population control. Even if population control were warranted, the large number of DCCO's in the Great Lakes, and the high degree of intercolony movement, would make control efforts ineffective unless they were done intensively and in a very coordinated manner. Unfortunately, the biological data needed to know where and when to direct control efforts and how best to reduce populations, are lacking. Significant administrative and social hurdles would also have to be overcome. And it is unclear which agency(ies) would be responsible for enacting population control, or where the financial and human resources would come from to do so.

Information Needs

The Great Lakes Cormorant Group that met in Ohio identified the following information and research needs:

1. Better data on the number, distribution, and trends of DCCO's nesting in the Great Lakes. This includes refinement of survey techniques and enlistment of a network of survey cooperators.

2. Better data on the productivity, survivorship, sources and sinks, and intercolony movements of DCCO's nesting in the Great Lakes.

3. Better data on the migration routes and winter distribution of Great Lakes DCCO's. This could involve banding and satellite telemetry.

4. Better documentation of the effects of DCCO's and other factors on sport fish populations. This includes population modeling.

5. Food habits of DCCO's in Lake Erie.

6. Better documentation of the effects of DCCO's on vegetation.

7. Better documentation of the effects of egg oiling on DCCO's. Specifically, when and how often should it be done, and will oiling the center of a colony disrupt nesting sufficiently to cause significant population reduction?

8. Better documentation of the efficacy of shooting and poisoning DCCO's to decrease economic losses and to enhance nonlethal control methods.

Management Considerations

Possible Options

There is a gradation of management options from no control to widespread control of DCCO numbers. Control includes nonlethal harassment of birds, which would be preferred whenever possible over lethal means. Options identified for discussion purposes are as follows:

1. No control of DCCO numbers, except possibly in specific local areas if birds are found to be having significant, negative ecological impacts on habitats or other species.

2. No control of DCCO numbers.

3. Widespread control of DCCO numbers to possibly protect the forage fish base, and sport and commercial fish stocks.

Management Implications

Efforts will continue to be made by MNR in cooperation with other parties to adequately monitor and research DCCO populations and their effects on fish stocks, habitats, and other species. This information is needed to further determine what, if any, management actions should be taken in the future. Some efforts and costs will be involved regardless of the management option chosen. Increased public information and continuing consultation is needed to address DCCO management concerns successfully.

In reviewing the options, it appears that possible control of DCCO's at specific local areas, where supported by studies and analyses, may be appropriate. This is consistent with MNR's goal of managing natural resources on an ecosystem basis. This option may not be supported by those advocating more widespread DCCO control but might be viewed by most people as a reasonable course of action. Any proposal to conduct DCCO control on a local area would require public consultation through the Ontario Environmental Bill of Rights process.

Not permitting any DCCO control appears extreme with regard to responsible natural resource management. For example, it is possible that DCCO's may have significant negative impacts on endangered or threatened habitats and other species, including fish, in specific local areas. A total prohibition of control likely would be opposed by most sport and commercial fish interests, as well as by many naturalists and others interested in maintaining biodiversity in Ontario's ecosystems.

Widespread control of DCCO numbers over wide geographic areas brings up a range of implementation issues. Any wide-scale control of DCCO's would be costly, would likely require international cooperation to be effective in the long term, and would need to be ongoing. It is also likely that the rapidly increasing DCCO population will stabilize and possibly decrease in response to density-dependent mortality factors such as Newcastle disease. Widespread DCCO control could result in maintaining DCCO populations at a continuing high level by preventing them from reaching the critical levels where natural factors, such as disease, could come into play and bring about a population crash and long-term stability at significantly lower levels. Any wide-scale or Provincewide control efforts might be strongly opposed by some naturalists, other environmental groups, and many members of the general public.

In conclusion, the Ontario Ministry of Natural Resources plans to continue to consult with other Federal, Provincial and State agencies, and interested parties within Ontario, as approaches to DCCO management are developed and continue to evolve with the availability of new information.

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